Process for producing a component with improved weldability and/or machineability from an alloy

The invention relates to a process for producing a component with improved weldability and/or machineability from an alloy in accordance with claim 1.

US 5,938,863 has disclosed a nickel-based superalloy which contains additions of carbides in order to improve the fatigue properties.

US 6,120,624 has disclosed a heat treatment for a nickel-based superalloy prior to welding, in order to avoid the formation of cracks during heat treatments after welding. In this case, very low cooling rates (3F/min = 1.66°C/min or less) are used during the heat treatment.

US 4,579,602 and US 4,574,015 have disclosed heat treatments for cast superalloys in order to improve the forging of these materials.

It is known from US 5,374,319, US 5,106,010 and EP 478374 to heat the locally delimited weld zone of a component to temperatures above the aging temperature. This leads to stresses in the component which is held at different temperatures.

During production of a component from an alloy, the component has to be machined in various intermediate production steps. Often, the alloy does not have the desired properties to allow it to be optimally machined.

For example, the alloy may be relatively brittle, making machining (straightening, cutting, grinding machining) more difficult.
It is often also necessary to weld cracks or holes, but the welding properties of the alloy are often poor.

Therefore, it is an object of the invention to overcome the above problems.

The object is achieved by a process for producing a component with improved weldability and/or machineability from an alloy in accordance with claim 1.

The subclaims list further advantageous process steps.
The measures listed in the subclaims can be combined with one another in advantageous ways. In the drawing:

Figures 1, 2	shows examples of time curves for the temperature of an alloy during a production process, and
Figure 3	shows various microstructures of an alloy.

Figure 2 shows an example of a time curve for the temperature of an alloy during the production process.

The alloy can be hardened, for example, by precipitations, such as for example an iron-base, nickel-base or cobalt-base superalloy.

The alloy can be sintered from a powder to form a component or can be directionally solidified or cast as a melt. Other forms of production are also conceivable.

If the alloy for a casting process has melted, the temperature is greater than the melting point $T_{liquidus}$. The melt is cast (left-hand part of the figure) and then cooled more or less slowly, in a controlled or uncontrolled way, so that the temperature is below the solidus line $T_{solidus}$. The component has then solidified. The component is, for example, cooled to room temperature (the point where the temperature axis T intersects the time axis t).

The casting process is followed, for example, i.e. not necessarily, by a re-densification, in particular immediately after the casting process, i.e. without cooling of the component after casting.
The re-densification is effected, for example, by hot isostatic pressing (HIP), (region I, Fig. 2) or possibly also by sintering, in order to close up defects, such as for example pores, voids, etc.
The re-densification may also be carried out after other production steps, for example after welding. The temperature during the re-densification (for example HIP) is below the solidus line $T_{solidus}$ of the alloy of the component.

In this stage (with or without re-densification), the components which consist of this alloy are machined (for example directionally or by cutting or grinding machining), and/or welding repairs of defects in the component are carried out, in particular at room temperature.

Often, however, the properties of the alloy of the component are not suitable for the mechanical processing conditions (weldability and mechanical processability).

A subsequent improvement heat treatment according to the invention, which leads, for example, to coarsening of the precipitations, for example by means of an overaging heat treatment, which leads to overaging of the structure of the allow, alters the microstructure of the component in such a way that the processability of the alloy is improved compared to the untreated microstructure. The microstructure features include, inter alia, the crystal structure, precipitations and secondary phases.

In particular, the overaging heat treatment indicated by way of example can directly follow the re-densification process, in particular in the same furnace, or after casting or sintering. There is no cooling (Fig. 2, transition between regions I, II) or only insignificant cooling of the component.
If the re-densification process is carried out by an HIP process, the pressure can remain unchanged, be slowly lowered or withdrawn during the improvement heat treatment.
A holding time at the temperature for the improvement heat treatment can in this case be dispensed with or reduced, since this time has already been partially or completely effected by the holding time for the HIP aftertreatment.
The overaging heat treatment, if appropriate after a holding time at a temperature, is achieved by a low cooling rate of greater than or equal to 2°C to 5°C, in particular from 2°C to 3°C per minute, in particular 2.33°C/min, immediately after the re-densification process (region II, Fig. 2).

Figure 1 shows the time curve when the component is being removed from the hot isostatic press and transferred into a different furnace.

The overaging heat treatment is achieved by heating up to a defined temperature, if appropriate with a holding time at this temperature (in the sequence shown in Figure 2, the heat-up operation is dispensed with), and, for example, by a low cooling rate of greater than or equal to 2°C to 5°C per minute, in particular from 2°C to 3°C per minute, in particular 2.33°C/min (region II, Figure 1).

An overaging heat treatment for IN738LC, which also leads to coarsening of the precipitations, has, for example, the following parameters:
heating at 10°C - 25°C/min (if necessary),
holding temperature/time 1180°C + 0°C - 10°C/holding time if appropriate 3h,
cooling at 2°C - 3°C/min, in particular 2.33°C/min, down to 950°C, followed by cooling in air.
The same parameters are used for IN939.
For Rene80, the holding temperature is 1204°C ± 15°C. The holding temperatures for the overaging heat treatment are also, for example, the HIP temperatures.
However, they may be higher or lower.

The overaging heat treatment effects overaging of the γ' phase, with the result that the ductility of the base material is significantly increased.

This overaging heat treatment, by way of example, improves the weldability of the alloy, in particular at room temperature, compared to the untreated alloy. Moreover, the improved mechanical ductility of the alloy compared to the untreated alloy means that the component can be more successfully

straightened (mechanically deformed) and/or more successfully machined by cutting or grinding.

The microstructure produced in this way may have properties which are worse than those of the microstructure prior to the heat treatment for the subsequent application area of the component, such as for example high-temperature use.

On account of the poor welding and straightening properties, hitherto high-strength nickel superalloys, such as IN939, Rene80 and IN738LC, have not been used in particular for large and thin-walled components, such as for example combustion chamber linings. These alloys include the γ' phase in order to increase their strength and can now be machined and used without restrictions by the process according to the invention (with welds).
Hitherto, the material of choice was Hastelloy X. This material can be welded better but has a limited high-temperature strength and straightenability compared to the other classes of materials.

After the overaging heat treatment, any defects (cracks, holes, etc.) are repaired, for example by means of microplasma powder surfacing or plasma powder surfacing.
In principle, it is also possible to use other welding processes, such as manual tungsten inert gas welding.
The weld locations formed during welding can if appropriate be beaten (hammered), which leads to cold work-hardening, since internal compressive stresses are induced. It is also possible for pores or other defects to be reduced or eliminated in this way.

This is followed, for example, by cold-straightening of the component in corresponding equipment in order to correct the geometry of the component.

Then, by way of example, solution annealing (at a temperature of greater than or equal to 1180°C up to, for example, 1200°C

for the abovementioned materials) can be carried out on the component, with subsequent rapid cooling (for example 20°

- 40°C per minute down to 800°C, followed by cooling in air), i.e. cooling which is faster than the cooling rate during the improvement heat treatment.
This "extinguishes" the overaged structure again, i.e. the coarse precipitations at least partially disappear and the component regains its good high-temperature properties of the alloy, for example by a finely dispersed γ' structure being established (rapid cooling).

The microstructure may have better properties for the application area of the component than the microstructure which the component had after the heat treatment for improving the processability.

During the overaging heat treatment of the materials with the γ' phase, this γ' phase is dissolved. When the γ' phase has dissolved, slow cooling takes place, during which the γ' phase is precipitated and correspondingly coarsened. The coarsening leads not only to a rise in the mean diameter of the γ' phase, but also, for example, to spheroidization of the γ' phase, i.e. it is less cubic and more in platelet form. Coarsening of this type leads to an increased ductility.
In the case of other materials which do not have a γ' phase, a corresponding heat treatment is carried out, altering the microstructure in such a way that it improves the processability of the component, in particular at room temperature.

The process for improving the processability of the alloy can be used for newly produced components and for components which have been used (refurbishment). In this case, the procedure is, for example, as follows.

The used component is cleaned (removal of oxidation/corrosion products) and, for example, any coatings are removed. This is followed by assessment of the component, i.e. cracks and pores are detected.
An overaging heat treatment is then carried out, followed either by welding repair of the cracks and pores at room temperature or straightening of the component.
If appropriate, this is followed by cold-forming (beating or hammering) of the weld locations produced in this way.
This is again followed, for example, by a heat treatment (for example solution annealing) in order to establish the desired finely dispersed γ' structure.
If appropriate, there then follows a further subsequent treatment of the weld locations, for example a local heat treatment. The solution annealing takes place, for example, at the same temperature as the temperature used for the overaging heat treatment, but with faster cooling, in order to prevent the coarsening of the γ' structures. In this case, the cooling is carried out so quickly that the γ' phase is not completely precipitated, but rather is forced to remain at least partly dissolved.
If appropriate, age-hardening can then be carried out in order to precipitate the desired γ' structure (fine particles in block form).

In particular a weld filler of a similar analysis to the base metal or a weld filler of the same composition as the component is used during welding. The term "of a similar analysis to the base metal" means that it has approximately the same composition as the component or has the same high-temperature

properties as the base material. In this case, by way of example, the constituents

of the weld filler are in the same relative proportions as in the material of the component.
If appropriate, it is possible to dispense with weld fillers.
In particular, weld fillers which are not very resistant to high temperatures should be avoided.
If the weld filler can be hardened, i.e. its strength increased, by precipitations, the weld location scarcely reduces the strength of the component, if at all.
The weld filler should include at least 35% by volume (in microsection) of the precipitations (for example the γ' phase).

The beating of the weld location after welding suppresses the formation of cracks during a first heat treatment after the welding.

Only the combination of the overaging heat treatment and the beating allows welding at least with a similar analysis to the base metal at room temperature in order to produce good, crack-free weld locations.

The overaging temperature of 1180°C for IN939 is deliberately selected to be higher than what is known from the prior art (1160°C, US 6,120,624).

An example of a subsequent heat treatment after the welding looks like this:

heating at 10°C - 25°C/min to a holding temperature for a certain time,
cooling at 20°C - 40°C/min, so that the overaging structure is dissolved.

Heating at 10°C - 25°C/min to a holding temperature for a certain time (solution annealing),
cooling at 20°C - 40°C/min

and if appropriate

heating at 10°C - 25°C/min to a defined holding temperature for a certain time,
cooling (age-hardening heat treatment).

The desired finely dispersed γ' phase is restored for use of the component, in order to achieve the required mechanical properties.

Figure 3 shows various microstructures of a superalloy.

This example shows the microstructure of the alloy IN738.

Figure 3a) shows the alloy with a cubic primary γ' phase and a fine secondary γ' phase, resulting in a high-strength alloy which has a low ductility.

Figure 3b shows an overaged microstructure which includes a γ' phase in platelet form, but no secondary γ' phase. This microstructure has a higher ductility than that shown in Figure 3a.